



Parasitic illnesses associated with the consumption of fresh produce — an emerging issue in developed countries

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Foodborne transmission of protozoan parasites is an emerging issue in developed countries around the world. Specifically, the parasites *Cryptosporidium*, *Giardia* and *Cyclospora* have been linked to numerous foodborne outbreaks of diarrheal illness. Many of these outbreaks have been associated with the consumption of fresh produce imported from developing regions, where water quality, hygiene and sanitation may be sub-optimal, and where numerous surveillance studies have demonstrated the presence of these parasites on fruits and vegetables. However, illness outbreaks have also been associated with the direct contamination of fresh produce at the food handler/consumer level. The implementation of control measures at pre-harvest and post-harvest, as well as at the food handler/consumer level, will be crucial in minimizing the foodborne transmission of these parasites.

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Introduction

The protozoan parasites *Cryptosporidium* spp. and *Giardia duodenalis* (syn. *G. lamblia*, *G. intestinalis*) are commonly reported in humans and a wide range of domestic animals and wildlife worldwide [1,2[•]]. There have been nearly 20 species and genotypes of *Cryptosporidium* reported in humans [2[•],3[•]], but *C. hominis* and *C. parvum* account for the majority of human infections [4]. The infectious stages of *Cryptosporidium* and *Giardia*, known as oocysts and cysts respectively, are shed in very large numbers with the faeces of infected hosts. In humans, both of these parasites are primarily transmitted through the faecal-oral route, meaning person-to-person or animal-to-person (zoonotic),

or indirectly through contaminated drinking water [1,2[•],3[•]]. Foodborne transmission of *Cryptosporidium* and *Giardia* is less common, representing 8% and 7%, respectively, of domestically acquired illnesses due to these parasites reported annually in the U.S. [5]. Fresh produce contaminated with *Cryptosporidium* oocysts or *Giardia* cysts has been implicated in many of the foodborne illness outbreaks reported.

Cyclospora cayetanensis has only been relatively recently described [6]. While endemic countries have been identified, this protozoan parasite, which is specific to humans, is commonly reported worldwide [7,8^{••}]. *Cyclospora* is unlikely to be transmitted person-to-person as the oocysts only become infectious following a sporulation period in the environment (Figure 1). Consequently, it was originally considered to be a waterborne infection, but over the last 20 years *Cyclospora* infections have become almost exclusively foodborne in the U.S., and likely in other developed countries, accounting for up to 99% of illnesses [5]. Virtually all foodborne illness outbreaks involving *Cyclospora* infections have been associated with oocyst-contaminated fresh produce [7,8^{••}].

Cryptosporidium, *Giardia* and *Cyclospora* are all associated with enteric illness; diarrhoea being the most common symptom [1,4,7]. In immunocompromised hosts, illnesses associated with these parasites, especially *Cryptosporidium*, may be much more severe, and even life-threatening.

Foodborne transmission of these protozoan parasites is an under-recognized, but important, emerging issue, particularly in developed countries, due largely to the increasing globalization of the food trade, international travel, the increased number of immunocompromised and other susceptible individuals, and changes in consumer habits [7,9,10^{••}]. Fresh fruits and vegetables, particularly those that are typically eaten raw and are imported from developing countries, are of greatest concern in this regard. The infectious stages of protozoan parasites have been reported on a wide variety of fresh produce in numerous surveillance studies worldwide (Table 1).

A few other protozoan parasites of public health concern (e.g. *Toxoplasma gondii*, *Entamoeba histolytica*, *Blastocystis hominis*, *Cystoisospora belli*, and *Balantidium coli*) have also been reported on vegetables [11–15], and have been implicated in a few illness outbreaks linked to fresh produce [10^{••}]. In addition, outbreaks of orally acquired

Figure 1



Cyclospora cayetanensis sporulated oocyst visualized by differential interference contrast (DIC) microscopy.

Chagas' disease (*Trypanosoma cruzi*) associated with the consumption of fruits or unpasteurized juices have been reported in South America [10**].

This review discusses the emerging issue of foodborne protozoan parasites associated with fresh produce, focusing on *Cryptosporidium*, *Giardia* and *Cyclospora*. It highlights the prevalence of protozoan parasites on fresh produce worldwide and the foodborne illness outbreaks that have been reported. Finally, the possible sources of contamination and the challenges associated with the control of these pathogens on fresh produce are discussed.

Surveillance studies on fresh produce

Surveillance studies have been conducted in many countries around the world for the presence of protozoan parasites on a wide variety of fresh fruits and vegetables [9,10**]. The vast majority of these studies have been performed in developing countries in Africa, the Middle East, and Central and South America, where the issue has long been a public health concern, and where contamination of produce may occur more frequently. Interestingly, relatively few such studies have been reported from developed countries (Table 1).

In the case of *Cryptosporidium*, oocysts have been reported on a variety of fresh produce in Egypt [16], Saudi Arabia [14], Iran [17], Poland [18], Spain [19] and Canada [20**]. *Giardia* cysts have also been detected on fresh produce in a number of surveillance studies. For example, watercress and other leafy vegetables were recently reported to be contaminated in surveillance studies done in Egypt [16,21], and a variety of other vegetables were found to be positive for *Giardia* cysts in Saudi Arabia [14], Iran [22,23], Iraq [13], Spain [19], and the Philippines [24]. Dixon *et al.* [20**] also recently reported the presence of *Giardia* on leafy greens in Canada. *Cyclospora*-like organisms have been found on leafy greens and other fresh produce items in Egypt [16] and Nepal [25], and a recent Canadian study reported the presence of *Cyclospora* oocysts on leafy greens [20**].

Sources of contamination

Fresh produce may become contaminated with the infectious stages of parasites at any number of points from farm level to the food handler/consumer level. In general, contamination is much more likely to occur in developing countries where human infections are endemic and where water quality and levels of hygiene and sanitation may be sub-optimal. For this reason, fresh fruits and vegetables which are typically eaten raw and are imported from developing countries are of greater concern.

At the farm level, contamination of fresh produce may occur during production, harvesting, packaging, or transport. In the case of *Cryptosporidium*, *Giardia* and *Cyclospora*, contamination is associated with poor personal hygiene, and may occur directly from the hands of infected farm workers (or their equipment), or those who are in close contact with infected individuals. Direct contamination of fresh produce may also occur through the application of animal faeces (with the exception of *Cyclospora* which is reported only in humans) or human faeces ('night soil') as fertilizer to crop lands. Finally, direct access to crops by livestock and other animals represents another potential source of contamination with these parasites (Figure 2).

Indirect contamination of produce at the farm level may occur through the use of faecally contaminated water in irrigation, mixing of pesticides, or washing of produce, hands or equipment. This is a particular concern in regions where water treatment and sanitation systems are poor. Parasites have, in fact, been detected in irrigation water in numerous studies [19,26,27]. Wastewater irrigation, in particular, has been cited as an important source of contamination in a number of surveillance studies on fresh produce. *Cryptosporidium* and *Giardia*, for example, are commonly found in raw water sources which have been contaminated with human sewage or agricultural runoff. In endemic countries, *Cyclospora* oocysts are also frequently found in water sources used for these purposes.

Contamination may also occur at the food handler/consumer level. The direct contamination of fresh produce by food handlers who are themselves infected, or who have been in close contact with infected individuals, is likely a major contributor. In fact, a number of foodborne illness outbreaks, particularly those involving *Cryptosporidium* and *Giardia*, have been epidemiologically associated with this source of contamination (see next section). Because of the sporulation period required before *Cyclospora* oocysts become infectious, food handlers have only rarely been implicated in illness outbreaks associated with this parasite.

Illness outbreaks

Many illness outbreaks associated with these foodborne parasites have been reported worldwide, including a number of outbreaks of cryptosporidiosis associated with

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